# Obstacles and Opportunities in Offshore Wind

Mike Jacobs

American Wind Energy Association

Image courtesy of NEG Micon

# Ancient Resource Meets 21st Century Technology

# Expectations for Future Growth

- With PTC in place, installed base could grow by 2,000 MW per year in short-medium term
- 20,000 total installed by 2010
- 100,000 MW total could be installed in the U.S. by 2020

→ If total installed capacity grew at 18% per year, wind could contribute 6% of nation's electricity supply by 2020

# Benefits of Wind Power
## *Fuel Diversity*

- Domestic energy source
- Inexhaustible supply
- No fuel supplies reduces risks

David Zalubowski / AP file

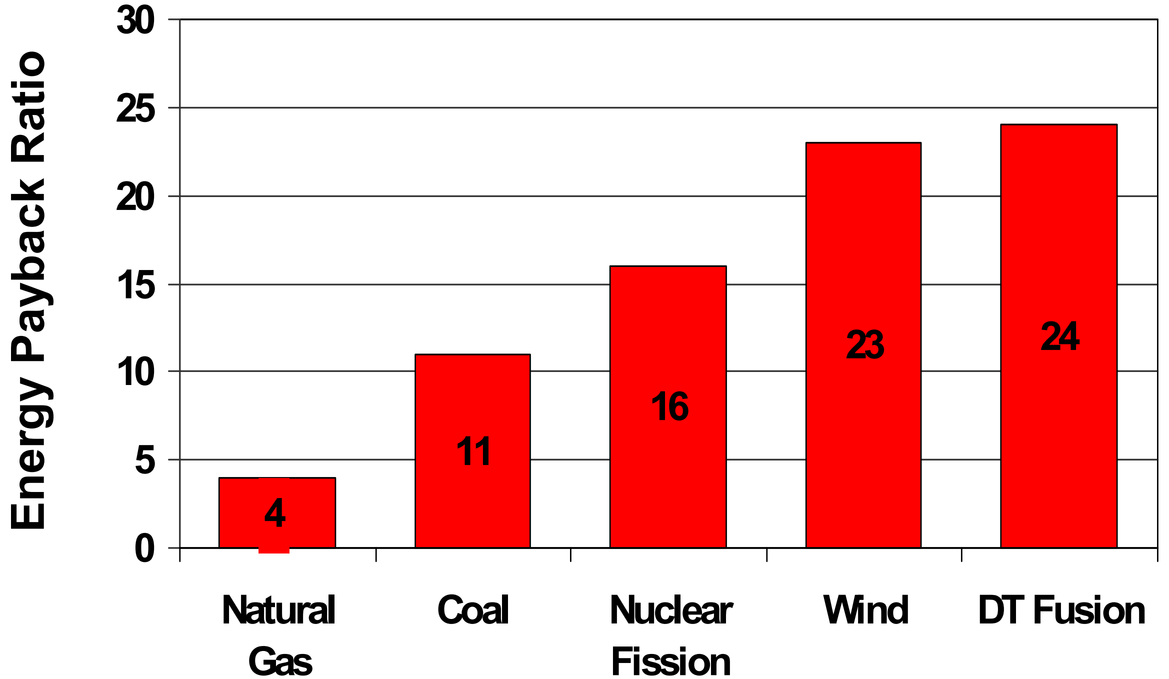
# Benefits of Wind Power
## *Environmental*

- No air pollution
- No greenhouse gases
- Does not pollute water with mercury
- No water needed for operations

# Turbine Technology Constantly Improving

- Larger turbines
- Specialized blade design
- Power electronics
- Computer modeling produces more efficient design
- Manufacturing improvements

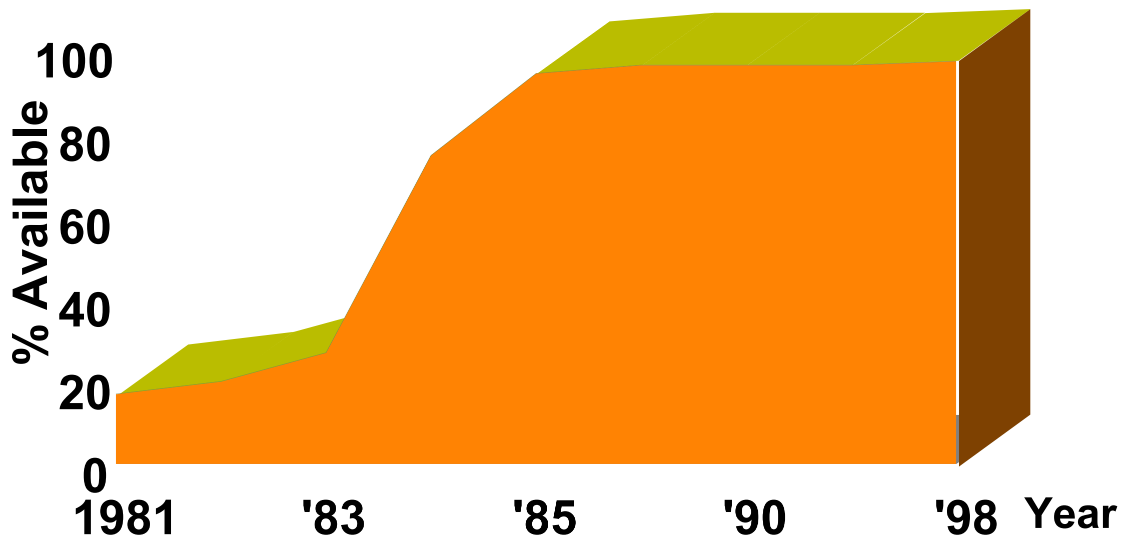
# Wind Energy Has One of the Best Energy Payback Ratios of Any Energy Technology



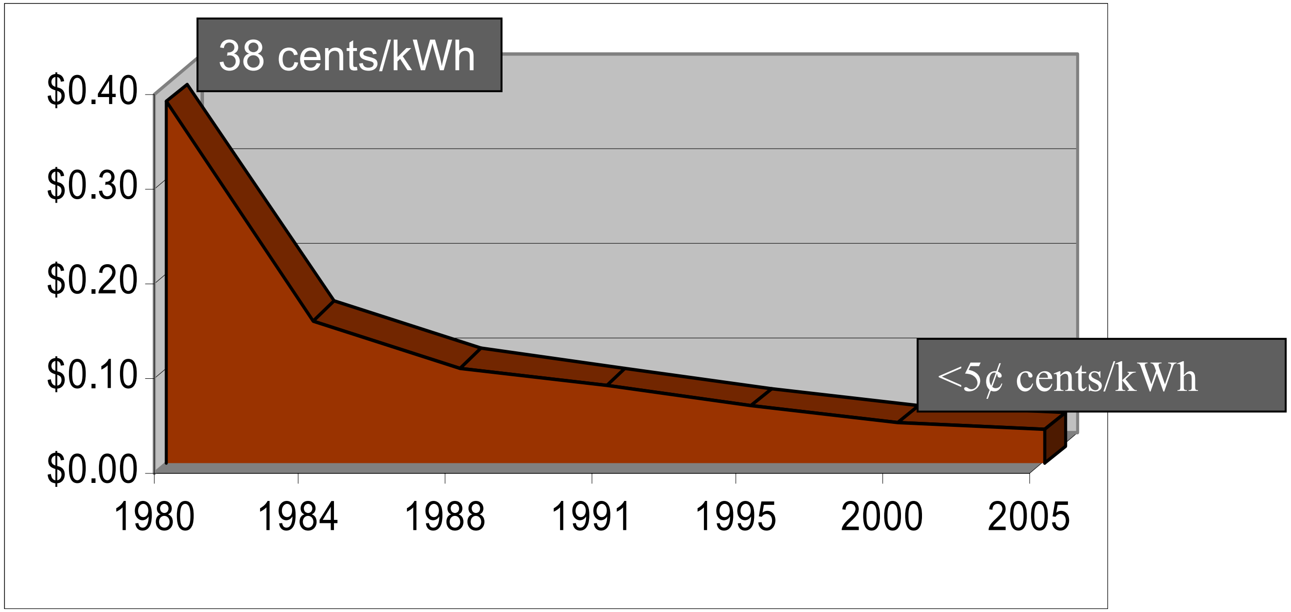

Paul J. Meier and Gerald L. Kulcinski, Fusion Technology Institute, University of Wisconsin, Madison, WI
Energy Payback Ratio compares the amount of energy produced by a power plant to the amount of energy it takes to build, run, and eventually decommission that plant. The more efficient the technology, the higher the EPR.

# Technology Improvements Lead to Better Reliability

- Drastic improvements since mid-80's
- Manufacturers report availability data of over 98%




# Bigger and Better Technology Leads to Lower Prices




Levelized cost at excellent wind sites in nominal dollars, including tax credit

# Improved Capacity Factor

- Modern wind turbines in the best sites are generating some electricity 70-90% of the time
- Average annual capacity factors can reach above 35% at good wind sites

# Technology Basics

# Fundamentals

Rotor

Nacelle

Tower

# Large Wind Systems

- Range in size from 660 kW to 3.6 MW (104 meter rotor diameter 73.5 meter hub height)
- Provide wholesale bulk power
- Require average wind speeds of 13 miles per hour

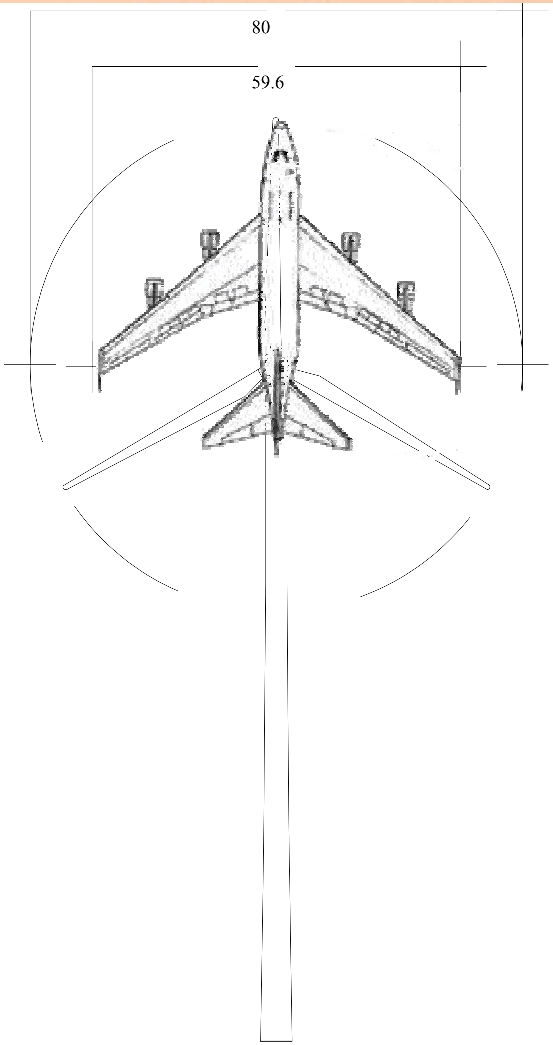
# Quantifying Wind Power Performance

| | |
|---|---|
| • 99% | Availability |
| • 70-90%+ | Operating time |
| • 25 – 35% | Annual Average Capacity |
| • 10 – 45% | Monthly *Accredited* Capacity |
| • <10% | Operating time at peak capacity |

# Typical Offshore Wind Turbines

# How big is a 2-MW wind turbine?

This picture shows a Vestas V-80 2-MW wind turbine superimposed on a Boeing 747 jumbo jet

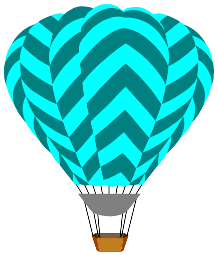
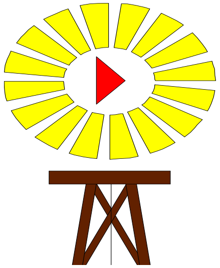
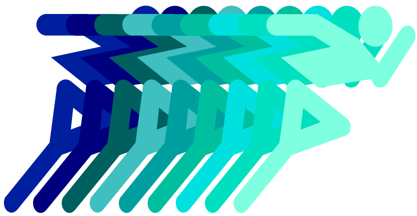


# Nacelle for 1.65-MW turbine

# Blade for utility-scale turbine

# Power in the Wind ($W/m^2$)

**= 1/2 x air density x swept rotor area x (wind speed)$^3$**

| $\rho$ | $A$ | $V^3$ |
|---|---|---|
|  |  |  |
| **Density = P/(RxT)**<br>P - pressure (Pa)<br>R - specific gas constant (287 J/kgK)<br>T - air temperature (K) | **Area = $\pi$ $r^2$** | **Instantaneous Speed (not mean speed)** |
| **$kg/m^3$** | **$m^2$** | **m/s** |

# Why Offshore?

- Higher-quality wind resources
  - Reduced turbulence
  - Increased wind speed
- Economies of scale on project and turbine size
- Proximity to loads -Population centers are near the coast
- Increased transmission options
  - Access to less heavily loaded lines
- Reduce land use and aesthetic concerns

# OFFSHORE WIND

- Availability of larger continuous areas
- Higher wind speeds
- Less turbulence
- Low wind shear
- Utilization of larger turbine designs

# Worldwide Offshore development

**Table 2-3: Installed offshore wind power in the World 2003 and 2004**

| Country | Installed MW 2003 | Accu. MW 2003 | Installed MW 2004 | Accu. MW 2004 |
|---|---|---|---|---|
| Denmark | 165 | 397.9 | 0 | 397.9 |
| Ireland | 25 | 25 | 0 | 25 |
| The Netherlands | 0 | 18.8 | 0 | 18.8 |
| Sweden | 0 | 23.3 | 0 | 23.3 |
| UK | 60 | 64 | 60 | 124 |
| **Total capacity - World** | **250** | **529** | **60** | **589** |

*Source: BTM Consult ApS - March 2005*

# Potential Issues

- Jurisdictional issues – Federal, state, local
- Capital costs
- High maintenance costs
- Shipping lanes and underwater environment
- Underwater power lines
- Public perception

# TECHNICAL & ECONOMIC SITING CRITERIA

- Wind Resource
- Water Depth  all existing  <20 meter depth
- Energy Loss
- Available Space
- Environmental Conditions
- Grid Connection

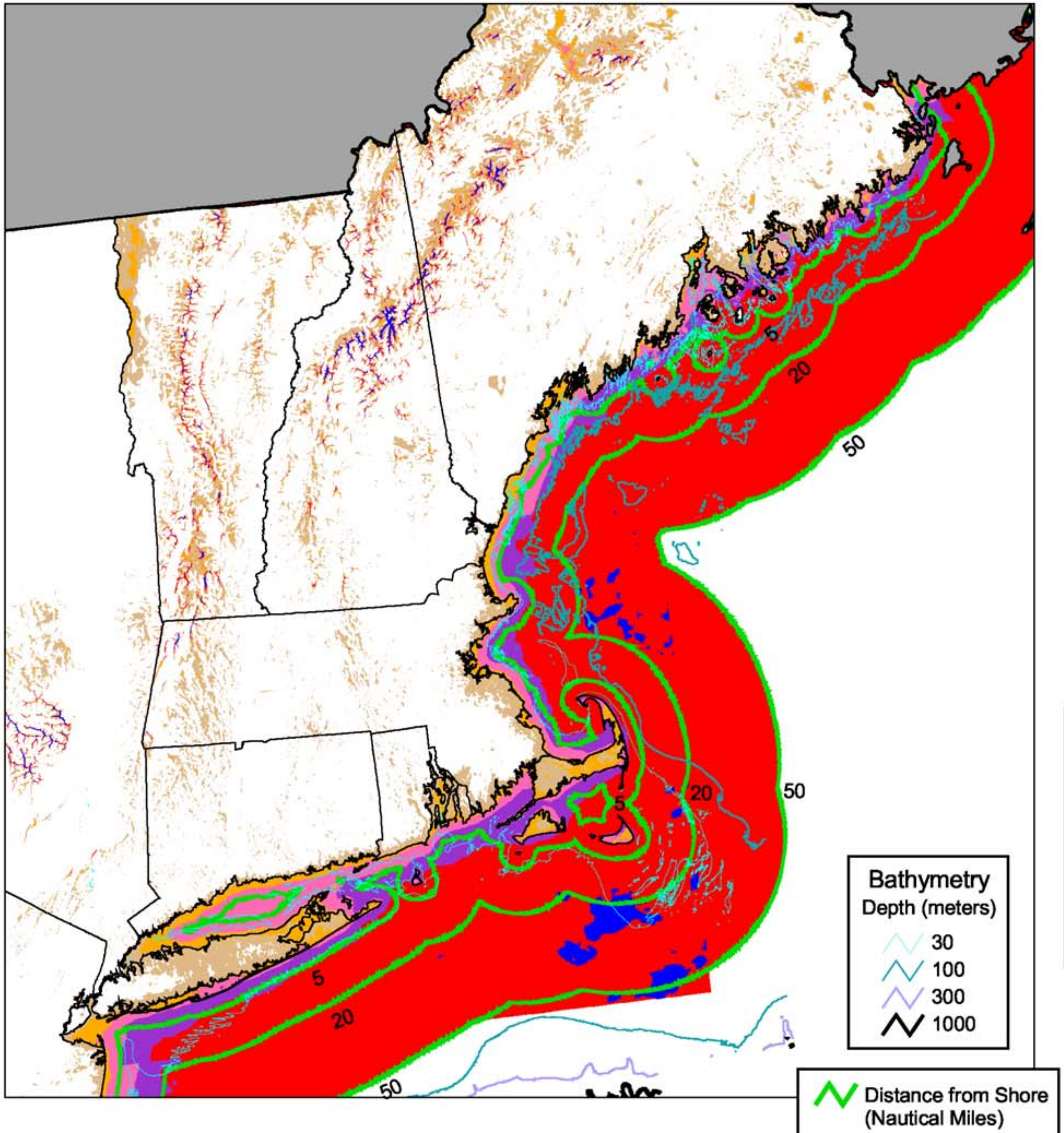
# Economic Sitting Issues

- Grid connection cost
- Foundation cost
- Accessibility
  - construction and O&M

# In view

# Wind Park Screening Criteria

- Renewable resource availability
- ISO New England grid connection availability
- Suitable land or offshore area
- Legal/regulatory constraints
- Engineering limitations




# New England Offshore Wind Resource Potential

All areas > 5 nautical miles offshore likely to be class 4 resource or better.

Area 5-20 nautical miles from shore (67% excluded):
10,300 sq. km. (51,500 MW)
1,980 sq km (9,900 MW) <30m depth

Area 20-50 nautical miles from shore (33% excluded):
33,800 sq. km. (169,000 MW)
540 sq km (2,700 MW) <30m depth

The wind power resource data for this map was produced by TrueWind Solutions using the Mesomap system and historical weather data, and has been validated by NREL.

The bathymetry contour lines were derived from NOAA's coastal relief models (nominal resolution 1 km) from NOAA's National Geo-physical Data Center.

Wind Power Classification

| Wind Power Class | Resource Potential | Wind Power Density at 50 m $W/m^2$ | Wind Speed[a] at 50 m m/s | Wind Speed[a] at 50 m mph |
|---|---|---|---|---|
| 2 | Marginal | 200 - 300 | 5.6 - 6.4 | 12.5 - 14.3 |
| 3 | Fair | 300 - 400 | 6.4 - 7.0 | 14.3 - 15.7 |
| 4 | Good | 400 - 500 | 7.0 - 7.5 | 15.7 - 16.8 |
| 5 | Excellent | 500 - 600 | 7.5 - 8.0 | 16.8 - 17.9 |
| 6 | Outstanding | 600 - 800 | 8.0 - 8.8 | 17.9 - 19.7 |
| 7 | Superb | > 800 | > 8.8 | > 19.7 |

[a] Wind speeds are based on a Weibull k value of 2.0

U.S. Department of Energy
National Renewable Energy Laboratory

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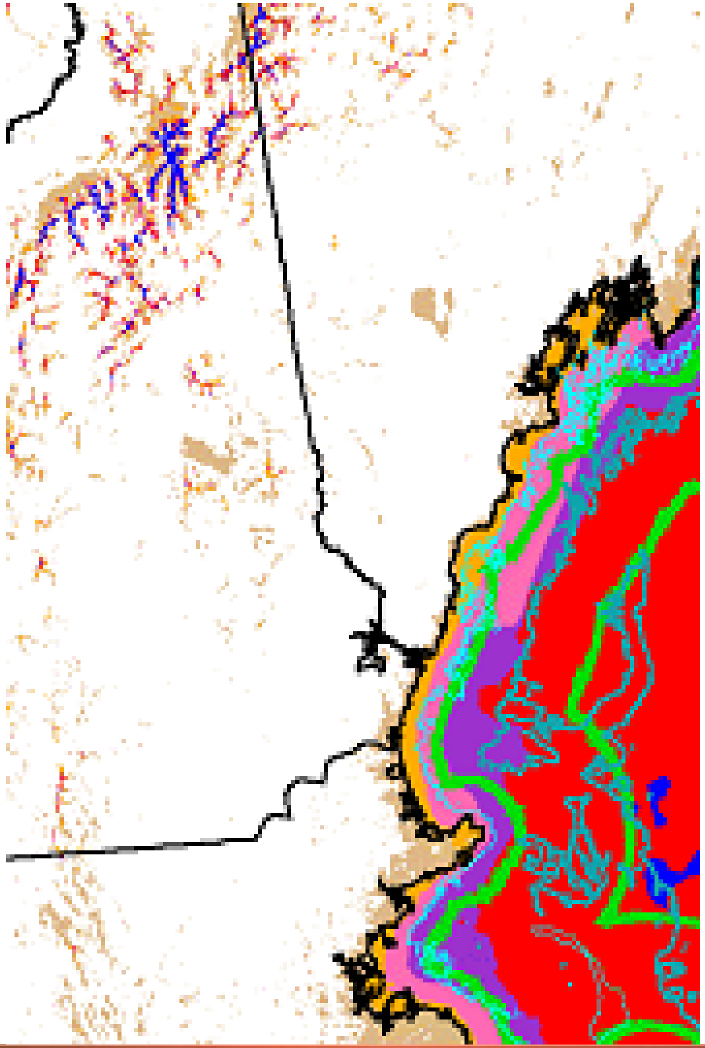

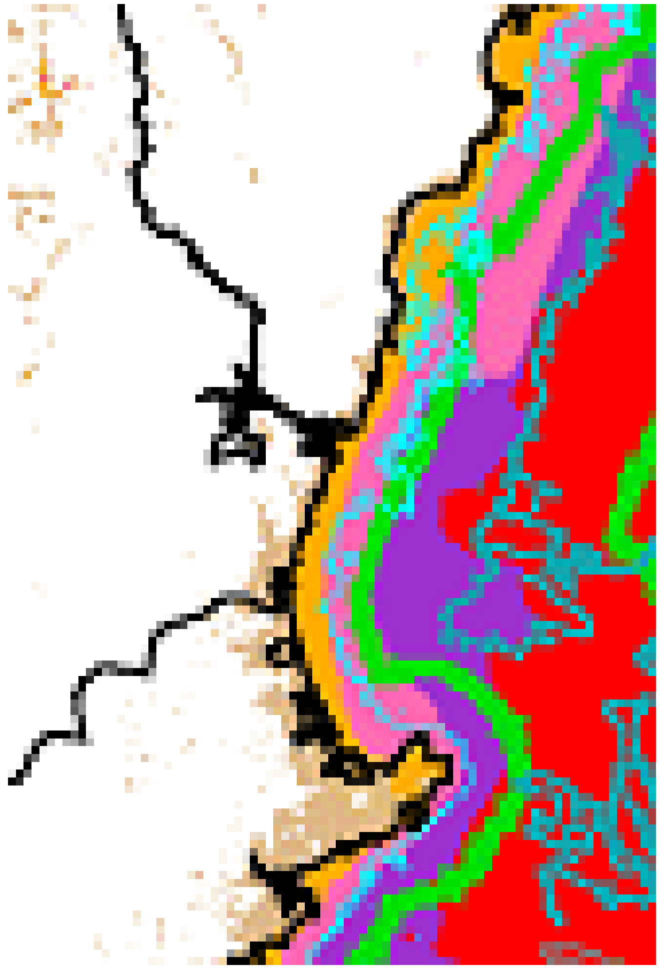

# Wind Project Siting

# The Offshore Environment

- Ambient turbulence
- Salinity, humidity & temperature
- Icing and snow
- Ship impact, breaking ice
- Waves and their variation in time & space
- Current, tides and scour effects
- Foundation behavior
- Marine growth

# Project Design Considerations

- Wind Resource
- Water Depths up to 15-20 m
- Appropriate foundation
- Icebreakers on towers?
- Transmission
  - Undersea cables may be buried to avoid anchors
- Tower height – blade tips must clear the tallest waves

# North America Offshore Challenges Comparison

- Wave heights in the Atlantic are on the average higher than those in the North Sea & Baltic
- The North Atlantic has 30% higher wave wave height than the North Sea
- Fetch length and wind speed is reason

# Met-ocean Design Parameters

- Wind
- Waves
- Wind and Wave correlation
- Currents
- Bathymetry & Sea Level Variations
- Marine Growth
- Icing and Sea Ice

# Important Concepts

- ESW-extreme storm wave (50 or 100 year return)
- Breaking wave
- Hydrodynamic loading
- Fatigue life
- Aerodynamic fatigue
- Hydrodynamic fatigue

# Design Criteria-Extreme Conditions

- Wind
- Wave
- Current
- Coincident Conditions (wind, wave and current)
- Coincident Flood Level (storm surge)

# Breaking Waves

- As waves approach shallower waters they become steeper and the probability of breaking increases significantly
- Plunging breakers occur in shallower water
- Plunging breakers cause very high impact loads
- Designing may be impractical due to large stiff structures and economic impact

# Environmental Siting Issues

- Aesthetics
- Bird collisions

# Bird Collisions

- Problem documented in Altamont Pass
  - One of nation's largest concentrations of federally-protected raptors
  - Abundant prey base
  - Heavy year-round raptor use

# Bird Collisions

- Problem at other wind installations? No. Altamont appears to be anomaly
- Minnesota: four year intensive post-installation field study
- PUC concluded: no significant impact
- Discontinued field studies

# Bird Collisions

- Foote Creek Rim, WY – heavy raptor use
- Turbine locations modified – fatalities very low
- Disturbance of sensitive species may be be problem in some locations – BUT
- There's nothing special about wind

# Spirit Lake Schools, Iowa

# Project Installation

# Want to Know More About Wind Power?

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